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Effect of muscle torques ratios and age category on judo fight

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Abstract

Background and Study Aim. The review of the studies that have examined fitness preparation of judokas shows that both dynamic and static strength testing protocols have been in use in judo. Therefore, it can be assumed that strength is an important component of athletes' motor preparation. The principal aim of the present study was to find proportions between relative muscle torques at each stage of athletes' development.

Material and Methods. The examinations involved e.g. biometric measurements (BH – body height, BM – body mass) and evaluation of body composition (LBM – lean body mass, FM – fat mass, PF – percentage fat content [12]). Body height was measured with Martin type anthropometer.

Results. The authors found that the ratios of relative muscle torques that define the position of the elbow, arm and trunk joints correlated with age of the judokas. We also observed a specificity of the judo fight and demonstrated the differences in the level of the indices of activity and effectiveness of attack depending on the age category. Ratios of the muscle torques measured under static conditions correlated with the indices of the course of the fight to different extent and they were in correlation with the age category. The level of achievement in judo tournaments in junior and cadet categories correlated mainly with the ratio of muscle torques in knee extensors to flexors. Lean body mass was calculated by deducting fat mass.

Conclusions. The obtained information might help coaches modify strength training regimes in cadet judokas in order to match model levels of ratios of relative muscle torques observed in seniors under static conditions. Biomechanical characteristics of professional athletes might be of importance to both coaches and scientists in the field of robotics.

Keywords: age • kinesiology • torque • martial arts

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INTRODUCTION

The review of the studies that have examined fitness preparation of judokas shows that both dynamic and static strength testing protocols have been in use in judo [1]. Therefore, it can be assumed that strength is an important component of athletes' motor preparation. Most previous studies [see review in reference 2] have used static handgrip test because handgrip is a key factor in transfer of forces to the opponent's body when performing throwing techniques or blocking these techniques. However, no correlations have been found to date between the level of achievement and static strength in the hand [2]. It was demonstrated that topography of muscle torques measured under static conditions correlated with the preferred technique used during the fight (hand or foot and leg techniques) [3].

A comprehensive diagnosis of judokas [4], which included testing of physical capacity, found the relationship between the athletes' age and the static strength in handgrip tests, arms and back. In cadets, total value of static strength was higher than in the untrained peers but it was significantly lower compared to juniors and seniors who were similar in these terms. In reference [4] no results relative to body mass were presented, which is particularly important since these athletes are divided into weight categories. Differences between the values of relative muscle torques measured under static conditions in judo cadets compared to the untrained peers were presented in e.g. reference [5]. It was observed that the frequency and effectiveness of technical and tactical actions that affect the score in the judo fight depend on weight category [6] and sports level [7,8]. Level of indices which characterize the course of cadets' fight correlated with physical capacity [9]. Although these findings seem to be significant for theoretical fundamentals of training, seeking correlations between the indices that characterize the course of the judo fight and ratios of relative static muscle torques

might be even more interesting as they might determine the level of achievement of an athlete in a particular tournament [5]. Knowing these proportions might not only improve the course of the fight but they also help prevent knee joint injuries [10], which are a common occurrence in judokas, who are particularly exposed to sprains [11].

The principal aim of the present study was to find proportions between relative muscle torques at each stage of athletes' development and provide answers to the following questions:

Are there differences in ratios of relative muscle torques between athletes from different age groups?

Are there relationships in individual age groups between the ratios of relative muscle torques and the fighting method and between these ratios and the level of achievement?

MATERIAL AND METHODS

The experiment meets the requirements with the 2008 revision of the Helsinki Declaration on the Experimental setup and procedures for the use of human subjects in research. The athletes and their legal guardians were also informed about the benefits of obtaining the results of examinations and limited risk during performance of non-invasive tests in the laboratory. The coaches expressed their interest in the experiment and agreed for participation of the athletes. The examinations involved e.g. biometric measurements (BH – body height, BM – body mass) and evaluation of body composition (LBM – lean body mass, FM – fat mass, PF – percentage fat content [12]). Body height was measured with Martin type anthropometer with accuracy of 1 mm, whereas body mass was evaluated by means of Sartorius F 1505 – DZA scales (Germany) with the accuracy of 1 g. Lean body mass was calculated by deducting fat mass from

Table 1. Characteristics of chronological age and training experience and basic indices of somatic build in study participants (mean, min, max, SD).

	Seniors (n=9)		Juniors (n=10)		Cadets (n=8)	
	$\bar{x} \pm SD$	min-max	$\bar{x} \pm SD$	min-max	$\bar{x} \pm SD$	min-max
Age (years)	21.9±0.99	20-24	17.4±0.73	16-18	15.4±0.55	15-16
Experience (years)	12.6±1.76	10-14	8.5±1.18	8-11	6.0±0.81	4-7
Body Height (cm)	180.2±5.39	171-188	180.5±3.70	172-185	177.1±6.25	170-186
Body Mass (kg)	82.9±6.62	71.0-92.1	85.4±10.45	72.1-101.1	71.6±7.50	56.4-82.0
Lean Body Mass (kg)	74.1±6.20	65.6-82.5	72.3±5.49	64.6-78.9	65.3±6.25	52.2-73.0

Table 2. Characteristics of standard measurement positions for maximal muscle torques [5].

Measured Muscle Group (Fmax)	Measurement Position	Angles in Joints Between Adjacent Segments		
SF & SE	Standing	Shoulder joint – 0°	Elbow joint – 0°	Radiocarpal joint – 0°
EF & EE	Standing	Shoulder joint – 90° (flexion)	Elbow joint – 90° (flexion)	Radiocarpal joint – 0°
HF & HE	Lying on back	Hip joint – 90° (flexion)	Knee joint – 90° (flexion)	Talocrural joint – 0°
KF & KE	Standing	Hip joint – 90° (flexion)	Knee joint – 90° (flexion)	Talocrural joint – 0°
TF & TE	Standing	Hip joint – 90° (flexion)	Knee joint – 90° (flexion)	Talocrural joint – 0°

Fmax – maximal strength; F – flexors; E – extensors; S – shoulder joint; E – elbow joint; W – radiocarpal joint; H – hip joint; K – knee joint; TC – talocrural joint (0° means that a foot of the measured extremity was in neutral position, i.e. at right angle to the lower leg); T – trunk.

body mass. Percentage fat content was calculated according to the formula for white postpubescent boys and adult males [12]. This information was then used for evaluation of fat mass.

Table 1 presents the characteristics of chronological age, training experience and basic parameters of somatic build in 25 judo contestants. All of them were in the middle of their competitive season and had scored places from 1st to 5th in Polish National Tournaments.

Measurements of muscle strength in hip, knee, shoulder and elbow extensors and flexors for the left and right body sides were carried out in the Department of Biomechanics. Based on these measurements, the authors calculated muscle torques. Muscle force was recorded during isometric contraction in test stands in standard positions in consideration of the relative position of body segments (Table 2). Before maximum isometric contractions were performed, the subjects were immobilized in the test stand by means of special holding devices in order to prevent using the muscles other than those measured in the study and to ensure reliable measurement conditions.

The force was recorded in a measurement circuit which featured Hottinger strain gauges, an analogue/digital (A/D) card and a PC. Data were stored and analysed by means of an Analog Digital Acquisition (ADA) application, licensed for the Department of Biomechanics. Based on the values of registered forces, maximal muscle torques were obtained for the measured muscle groups according to the formula (1):

$$M_{\max} = \frac{F_{\max}}{d} \quad (1)$$

where: Mmax [N·m] – maximal muscle torque in the measured muscle group, Fmax [N] – maximal

force developed during isometric contraction in the measured muscle group, d [m] – lever arm of external force (distance from biomechanical rotation axis in the joint to the line of dynamometer's operation).

Furthermore, relative values of developed muscle torques were calculated based on the formula (2):

$$M_w = \frac{M_{\max}}{m} \quad (2)$$

where: Mw [Nm·kg⁻¹] – relative muscle torque, m [kg] – body mass of a subject.

Dividing the relative values of muscle torques in extensors by the respective values of torques in flexors yielded ratios which characterize strength abilities in antagonistic pairs in lower extremities. In the case of upper extremities, relative values of muscle torques in flexors were divided by the respective values in extensors. This allowed for obtaining values over 1 in both cases, which reflects different topography of dominance of antagonistic muscle groups in lower and upper extremities.

Observations of the technical and tactical actions were carried out during sports competitions. Video analysis carried out in the Department of Theory and Methodology of Combat Sports (now Department of Theory of Sport and Kinesiology) consisted in calculation of the indices of the course of 175 fights (51 fights in senior group, 58 fights in junior group and 66 fights in cadet group). 373 technical actions which scored points for these contestants (3 to 10 points) and attacks without points (0 points) were recorded in total. Based on the collected data, indices which determine the activity and effectiveness of actions among

Table 3. Torque ratios in five main muscle groups in seniors, juniors and cadets (mean, min, max, SD)

Ratios	Senior (n=7)				Junior (n=10)				Cadet (n=8)				Significance of differences	
	\bar{x}	Min	Max	SD	\bar{x}	Min	Max	SD	\bar{x}	Min	Max	SD	test	p
EF/EE	1.63	1.18	2.23	0.35	1.48	1.28	1.70	0.15	1.11	0.76	1.56	0.27	F=8.37	0.002
SF/SE	0.99	0.71	1.48	0.30	1.50	1.08	1.89	0.30	1.32	0.84	1.60	0.24	F=7.08	0.004
TE/TF	2.00	1.83	2.19	0.12	2.63	2.26	3.20	0.32	1.83	1.26	2.81	0.61	H= 11.85	0.003
KE/KF	2.67	2.18	3.58	0.61	2.40	2.05	3.33	0.38	2.25	1.87	2.96	0.38	H= 3.88	0.144
HE/HF	2.39	1.84	2.70	0.28	2.09	1.37	3.15	0.54	2.77	1.22	6.96	1.86	H=1.14	0.567

F – flexors; E – extensors; S – shoulder joint; E – elbow joint; H – hip joint; K – knee joint; T – trunk.

the study participants were calculated. Activity index (WA) was calculated from the formula (3):

$$WA = \frac{\Sigma A}{NW} \quad (3)$$

where: ΣA is a total of the attacks, NW – is the number of fights the contestant fought. The activity index calculated for phase 1 was WA_1 , with WA_2 for phase 2. Another index, RWA (difference in the activity index), was also calculated to reflect variability of activity during competition. It was calculated as follows (4):

$$RWA = WA_1 - WA_2 \quad (4)$$

The effectiveness index (WS) is an arithmetic mean of the notes for attacks (WS_1 as calculated for phase 1 of the match and WS_2 for the second phase) (5):

$$RWS = WS_1 - WS_2 \quad (5)$$

Level of sports achievement was differentiated according to the following point scale:

preliminary fights: 1st place 3 points, 2nd place 2 points, 3rd place 1 point, 5th place 0.5 points; and

central competition: 1st place - 7 points, 2nd 5 points, 3rd 3.5 points, 5th 1.5 points, and 7th 0.5 points.

The indices of the course of the fight were calculated for the first three minutes (1) in seniors and the first two minutes in juniors and cadets (1). If extra time was used, it was included in the phase 2 of the fight (2).

Statistica package software was employed for the analysis of the results. The descriptive statistics were calculated and the comparison was made between the groups of cadets, juniors and seniors. ANOVA (F) or non-parametric ANOVA Kruskal-Wallis test (H) for ranks was used, depending on the fulfilment of the condition of normal distribution by variables. Tukey's multiple comparison test was used where ANOVA F-values were significant. Spearman rank correlation coefficient (R) was also employed for the analysis. Statistical significance level was set at $p \leq 0.05$.

RESULTS

a) Differences in torques across age group

Table 3 presents the descriptive statistics for the ratios of torques in five main muscle groups in seniors, juniors and cadets.

The results of comparison of mean torque ratios were statistically significant ($p < 0.01$) for elbow joint, shoulder joint and body trunk. A characteristic pattern of means was observed in EF/EE ratio, where the advantage of flexors over extensors was the highest in seniors, medium in juniors and the lowest in cadets. Tukey's multiple comparison test demonstrated that cadets differed significantly from juniors ($p < 0.05$) and seniors ($p < 0.01$). The ratio of flexors and extensors of shoulder joint (SF/SE) in seniors was balanced (≈ 1.0), whereas distinct advantage of flexors was found in younger contestants. The difference between seniors and juniors was statistically significant ($p < 0.01$). Mean muscle torque ratios in extensors and flexors differed statistically significantly ($p < 0.01$) and were significantly higher in juniors compared to seniors ($p < 0.001$). Juniors

Table 4. Indices of the course of the fights of seniors (S), juniors (J) and cadets (C) (mean, min-max, SD)

Ratio	Senior (n=7)				Junior (n=10)				Cadet (n=8)			
	\bar{x}	Min	Max	SD	\bar{x}	Min	Max	SD	\bar{x}	Min	Max	SD
WA	2.63	1.60	3.80	0.72	2.13	1.00	3.50	0.63	1.73	0.60	2.60	0.76
WA1	1.80	0.90	2.50	0.60	1.03	0.33	2.00	0.45	1.16	0.40	2.40	0.61
WA2	1.37	1.00	1.80	0.28	1.56	0.67	2.20	0.56	0.94	0.33	2.00	0.59
RWA	0.43	-0.70	1.00	0.67	-0.53	-1.67	0.49	0.73	0.22	-0.64	2.07	0.85
WS	2.84	1.64	4.77	1.00	3.42	2.42	6.83	1.37	4.51	3.26	6.25	1.05
WS1	3.10	0.00	5.86	1.77	4.04	2.17	7.00	2.02	5.25	3.29	8.50	1.76
WS2	2.11	0.00	3.50	1.24	3.24	0.75	6.75	2.06	2.96	0.00	7.00	2.71
RWS	1.00	-2.60	3.90	2.14	0.81	-3.19	6.25	2.95	2.30	-3.00	8.50	4.20
PO	4.00	0.00	14.00	5.07	3.30	1.00	6.00	1.51	2.88	0.00	9.00	3.01

also dominated in this respect compared to cadets ($p < 0.05$). Nearly twice higher muscle torques were observed in extensors compared to flexors in knee and hip joints across all the three age categories. Intergroup differences were not statistically significant ($p > 0.05$).

b) Indices of the course of judo fight in relation to muscle torques ratios

Table 4 presents the levels of indices characterizing the course of the judo fights fought during competitions by the athletes included in the study.

A strong rank correlation was observed in seniors between RWA and the ratios of muscle torques: TE/TF ($R = 0.84$, $p < 0.05$) and HE/HF ($R = 0.72$, $p = 0.07$, i.e. insignificant tendency). A strong positive correlation existed between the value of the effectiveness index in attack in the second part of the fight WS2 and SF/SE ratio ($R = 0.75$, $p = 0.05$). In juniors, the value of activity indices correlated moderately ($p < 0.05$), either positively or negatively, within the following pairs: WA with TE/TF ratio ($R = -0.68$), WA1 with KE/KF ratio (0.64), WA2 with SF/SE ratio (-0.70). RWA depended on SF/SE ratio ($R = 0.65$). Level of effectiveness index WS correlated negatively with EF/EE ratio (-0.64), WS2 with KE/KF ratio ($R = 0.63$) and with RWS ($R = -0.64$).

In cadets, the effectiveness of attack (WS and WS1) showed strong correlation with EF/EE ratio (0.79 and 0.77, respectively, $p < 0.05$).

Level of sports level (PO) in the group of seniors did not correlate with ratios of the measured muscle torques. The most numerous correlations between the muscle torque ratios and indices of

the course of the fight were observed in the junior group. The rank of the sports level depended on the KE/KF ratio, with strong statistically significant correlation ($R = 0.79$; $p < 0.01$). In the group of cadets, correlation between the rank PO and KE/KF ratio was negative ($R = -0.74$).

DISCUSSION

We previously stated that “Although judo contestants exhibit similar relative strength to untrained peers, many-year training causes that they demonstrate higher strength in the muscles which are active when pulling or lifting the opponent during performing throws. Antigravity muscles are capable of developing particularly high force in these persons and play an essential role when throws are performed.” [5]. In this study we have verified how proportions of relative muscle torques measured in static conditions correlate to age and the course of the judo fight. The biomechanical approach to judo performances can be fruitful for both biomechanics specialists and judo coaches [13]. The results obtained in this study might be used in the practice of judo training, where the athletes must maintain balance and perform complex movements (throwing techniques in particular). They might also be of much interest to the scientists who investigate human-robot interactions and attempt to define the principles of robot construction in order to create even more perfect machines that utilize biological relationships observed in athletes (judokas). This empirical work is relevant for better understanding of the regularities in proportionality of torques across different age groups. It shows the relation between strength indices and performance level during the course of judo tournament fights. The

collected data might be used in construction of training aids and provide a model for the design and construction of the equipment based on bio-feedback principles.

CONCLUSIONS

In conclusion, the value of muscle torque ratios which determine the position of the elbow, shoulder or trunk joints correlated with judoka age. The specific method of fighting was found for each age category, reflected by the differences in the level

of activity indices and the effectiveness of attack. The level of achievement in judo tournaments in the categories of juniors and cadets depended mainly on muscle torque extensor/flexor ratio in knee joints. Further research should be conducted in the field of the effect of isokinetic strength on judo performance. Investigations of the relationships between the parameters characterizing the level of physical and tactical preparation in senior groups might be particularly valuable for the theory and practice of training.

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